Acoustical Measurement of Sound System Equipment according IEC 60268-21

KLIPPEL live

a series of webinars presented by

Wolfgang Klippel
1. Modern audio equipment needs output based testing
2. Standard acoustical tests performed in normal rooms
3. Drawing meaningful conclusions from 3D output measurement
4. Simulated standard condition at an evaluation point
5. Maximum SPL – giving this value meaning
6. Selecting measurements with high diagnostic value
7. Amplitude Compression – less output at higher amplitudes
8. Harmonic Distortion Measurements – best practice
9. Intermodulation Distortion – music is more than a single tone
10. Impulsive distortion – rub & buzz, abnormal behavior, defects
11. Benchmarking of audio products under standard conditions
12. Auralization of signal distortion – perceptual evaluation
13. Setting meaningful tolerances for signal distortion
14. Rating the maximum SPL value for a product
15. Smart speaker testing with wireless audio input

Acoustical testing of a modern active audio device
8th KLIPPEL live:
Harmonic Distortion Measurements – best practice
谐波失真测量 – 最佳实践

今日话题 Topics today:

• IEC 60268-21定义的方法概述 Overview on Methods defined by IEC 60268-21
• 谐波失真的指标(绝对或者相对？) Metrics for Harmonic Distortion (absolute or relative ?)
• 符合IEC标准概述的测量以及其他有用测试方法 Measurement according to IEC Standard Overview and other useful test methods
• 结果解读 Interpretation of the results.
• 实际演示 Practical demos
非线性症状：谐波失真
Nonlinear Symptom: Harmonic Distortion

single tone stimulus \rightarrow \text{Nonlinear System} \rightarrow \text{output}

Fundamental + Harmonics + Subharmonics + Noise

sound pressure spectrum

Amplitude

frequency

$2f_1$, $3f_1$, $nf_1$

subharmonics

harmonics

$2^{nd}$ $3^{rd}$ $r^{th}$
单音是好的激励信号吗
Is a Single Tone a Good Stimulus?

复杂度的激励信号

Single Tone  Two Tone  Multi Tone  Noise  Audio Signal

PRO:
• 易于生成 simple to generate
• 揭示谐波、DC分量 reveals harmonics, dc component
• 揭示基波压缩的最大输出 reveals maximal output of fundamental compression
• 可进行超快速扫描测量 Ultra-fast sweep measurements are possible
• 适合异音测量 (参考Klippel live第10期) good for rub&buzz (see section #10 of the Klippel live)

CONTRA:
• 不产生互调成分 no intermodulation components are generated
• 对非线性行为评估不全面 not a comprehensive assessment of the nonlinear behavior

Spectral Analysis
(Fourier Transform, High-pass and bandpass filter, ...)

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Poll:

Which stimulus do you use for measuring the harmonic distortion?

A. 单音（稳态） Single tone (steady state)
B. 正弦步进（可变音调序列） Step sine (sequence of switched tones)
C. 正弦猝发音（整形短音+停顿） Sinusoidal burst (shaped short tone + break)
D. 连续正弦chirp Continuous sinusoidal chirp
E. 其他 Other
### How to measure Harmonic Distortion versus frequency?

<table>
<thead>
<tr>
<th>Techniques</th>
<th>Step Sine</th>
<th>Sinusoidal Burst</th>
<th>Continuous Chirp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distortion Separation</td>
<td>Spectrum (FT)</td>
<td>Spectrum (FT)</td>
<td>- Tracking Filter</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Windowed Impulse Filter (Farina)</td>
</tr>
<tr>
<td>Continuous Excitation</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Steady State</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Total test duration</td>
<td>Long</td>
<td>Long</td>
<td>Short</td>
</tr>
<tr>
<td>KLIPPEL modules</td>
<td>DIS</td>
<td>TBM</td>
<td>TRF, TRF-stepping QC-SPL task</td>
</tr>
</tbody>
</table>

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Sweep Speed of the Chirp

- Linear chirp
- Log. chirp with constant speed
- Chirp with increasing sweep speed
Poll:

Which sweep speed profile do you use?

A. 线性时频映射 With linear time frequency mapping
B. 对数时频映射 With logarithmic time frequency mapping
C. 扫描速度不断增加 With increasing sweep speed
D. 其他 Others
Shaped Logarithmic Sine Chirp

Amplitude depends on frequency
\[ u(t) = U(f(t)) \cos(2\pi f(t)t) \]

Frequency depends on time
\[ f(t) = f_{\text{start}} 2^{\beta t} \quad 0 \leq t \leq T_s \]

\[ \beta = \frac{1}{T_s} \log_2 \left( \frac{f_{\text{end}}}{f_{\text{start}}} \right) \]

Group delay response

Filter relative bandwidth

Filter absolute bandwidth

Amplitude spectrum
In a logarithmic chirp, harmonic components are measured before they are generated (non-causal).

In a spectrogram, the 2nd and 3rd harmonics can be seen along with the logarithmic chirp and sound reflections. The harmonic component was measured before it was generated (non-causal).

1 kHz

500 Hz

160 ms

Frequency

Time
Farina’s Harmonic Distortion Measurement

Reproduced chirp

Total Impulse response

Energy Time Curve

impulse response of the harmonics

impulse response of the fundamental
More to this topic …

Reference:
Demo: In-situ Measurement

Tool: Using a dedicated software module TRF (chirp stimulus) of the KLIPPEL Analyzer
Farina with Room Compensation

- The compensation filter compensates for the room influence.
- Reduces the ringing in the linear impulse response.
- Reduces the ringing in harmonic impulse response.
- Windowing can be applied to separate linear and distortion components (Farina technique).

→ Nonlinear distortion can be measured under non-anechoic conditions!
Accurate Harmonic Distortion

The total harmonic distortion (THD) in percent without compensation filter shows significant errors.

The room modes generate an error of 20 dB in the fundamental component and an error of more than 6 dB in the total harmonic components.

The total harmonic distortion (THD) in percent without compensation filter shows significant errors.

The THD with compensation filter corresponds to the expected results found in an anechoic environment.
Demo: Simulated Free/Far Field

Tools of the KLIPPEL Analyzer:

- Transfer Function TRF (chirp stimulus)
- In-Situ-Compensation (ISC)
- Nearfield Scanner (NFS)
**Best chirp for end-of line testing?**

- **Logarithmic chirp with constant sweep speed**
  
  \[ \beta = \log_2 \left(1 + \frac{1}{Q_{\text{max}}} \right) f_0 \]
  
  \[ = \text{const.} \]

- **Step Sine with fixed number of periods**

  \[ P_i = 1 + \left\lfloor \frac{Q_{\text{max}}}{8} \right\rfloor = \text{const.} \]

- **Chirp with increasing sweep speed**

  \[ \beta(t) = \log_2 \left(1 + \frac{1}{Q_{\text{max}}} \right) f(t) \]

- **Linear chirp**

  \[ \text{log sweep with constant speed} \]

- **Step Sine contains fixed number of periods at each frequency**

- **Chirp with increasing sweep speed**

  \[ \text{log. sweep with constant speed} \]

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Ultra-Fast Testing in Production

扫频速度增加的对数chirp

Logarithmic chirp with increasing sweep speed

 waveform of log. sweep with speed profile

linear sweep

log. sweep with constant speed

low sweep speed

log. sweep with speed profile

High sweep speed

Step Sine

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Sweeping Up or Down?

Ultra short testing < 0.5 s

振铃的问题 Problems of ringing:

- 高Q共振需要的衰减时间 > 50ms  High Q resonances need decay time of >50ms
- 基波被解读为谐波 Fundamental interpreted as Harmonics

→ 极快速测试使用向上扫频 Use UPWARDS SWEEP for extremely fast testing
More to this topic …

Reference:

- EOL测试的目标和特点 Targets and Particularities of EOL Testing
- 限制测量速度的物理原因 Physical reasons for limiting measurement speed
- 寻找最佳激励进行EOL测试 Finding best stimulus for EOL Testing
- 噪杂环境中的快速测试 Fast testing in a noisy environment
- 从生产中学习 Learning from Production
- 结论 Conclusions
目标 Objectives:
• 用一个指标描述失真的特性 Describing the properties of the distortion by a metric
• 理解与非线性的关系（根本原因） Understanding the relationship to nonlinearities (root cause)
• 评估对感知音质的影响 Evaluating Impact on the perceptual sound quality

诊断利用以下特性 Diagnostics exploits the following properties
• 偶次和奇次分量（2阶、3阶） Even and odd-order components (2nd, 3rd)
• 失真分量的能量总和THD Energetic sum of the distortion components (THD)
• 谐波失真的频率依赖性 Frequency dependency of the harmonic distortion
• 谐波失真的幅值依赖性 Amplitude dependency of the harmonic distortion
• 低阶和高阶失真 Lower-order and Higher-order distortion
• 所选失真分量的加权能量和 (高阶失真IEC 60268-21，HI-2失真) Weighted energetic sum of selected distortion components (higher-order distortion IEC 60268-21, HI-2 Distortion)
符合IEC 60268-21的谐波能量和
Energetic Sum of the Harmonics according IEC 60268-21

问题 Problems:

• THD(f) 绘制成与激发频率相关的曲线 THD(f) is plotted versus excitation frequency f
• THD通常由2阶和3阶分量主导 THD is usually dominanted by 2nd and 3rd-order components
• THD取决于$\tilde{p}_{ref}(f)$的定义（总信号、基波、指定频率范围的平均基波）THD depends on definition of $\tilde{p}_{ref}(f)$ (total signal, fundamental, mean fundamental in stated frequency range)

\[
\tilde{p}_{TH}(f) = \sqrt{\sum_{n=2}^{N} \tilde{p}_{nf}^2(f)}
\]

\[
\tilde{p}_{nrf}^2(f) = \tilde{p}_{ref}(f)
\]

\[
L_{TH}(f) = 20 \lg \left( \frac{\tilde{p}_{TH}(f)}{p_0} \right)
\]

\[
L_{THD}(f) = 20 \lg \left( \frac{THD}{100 \%} \right)
\]

\[
THD(f) = \sqrt{\sum_{n=2}^{N} \tilde{p}_{nf}^2(f)} \quad 100 \%
\]
Causes of THD in Sound Pressure
of an electro-dynamical loudspeaker

Total Harmonic Distortion (THD)

Fundamental

excitation frequency

resonance frequency

Kms(x) Kms(x)
Bl(x) Bl(x)
L(x)
L(i)
Cone Vibration

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广义信号流模型 Generalized Signal Flow Model

描述分离的非线性 describing a separated nonlinearity

1. **Distortion added to the input**

2. **Post-shaping**

3. **Pre-shaping**

4. **Feedback loop**

5. **Static Nonlinearity**

6. **Multiplier**

7. **Current**

8. **Voltage**

9. **Sound pressure**

10. **Highpass**

11. **Post-filter** $H_2(f)$

12. **Post-filter** $H_1,2(f)$

13. **Post-filter** $H_1,1(f)$

14. **Displacement** $L(x)$

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## The Particularities of Each Nonlinearity

<table>
<thead>
<tr>
<th>NONLINEARITY</th>
<th>INTERPRETATION</th>
<th>PRE-FILTER $H_{1,1}(f)$ (output)</th>
<th>PRE-FILTER $H_{1,2}(f)$ (output)</th>
<th>POST-FILTER $H_{2}(f)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stiffness $K_{ms}(x)$ of the suspension</td>
<td>restoring force</td>
<td>Low-pass (displacement $x$)</td>
<td>Low-pass (displacement $x$)</td>
<td>1</td>
</tr>
<tr>
<td>Force factor $B_l(x)$</td>
<td>electro-dynamical force</td>
<td>Band-stop (current $i$)</td>
<td>Low-pass (displacement $x$)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>nonlinear damping</td>
<td>Band-pass (velocity $v$)</td>
<td>Low-pass (displacement $x$)</td>
<td>1</td>
</tr>
<tr>
<td>Inductance $L_{e}(x)$</td>
<td>self-induced voltage</td>
<td>Band-stop (current $i$)</td>
<td>Low-pass (displacement $x$)</td>
<td>differentiator</td>
</tr>
<tr>
<td></td>
<td>reluctance force</td>
<td>Band-stop (current $i$)</td>
<td>Band-stop (current $i$)</td>
<td>1</td>
</tr>
<tr>
<td>Inductance $L_{e}(i)$</td>
<td>varying permeability</td>
<td>Band-stop (current $i$)</td>
<td>Band-stop (current $i$)</td>
<td>differentiator</td>
</tr>
<tr>
<td>Mechanical resistance $R_{ms}(v)$</td>
<td>nonlinear damping</td>
<td>Band-pass (velocity $v$)</td>
<td>Band-pass (velocity $v$)</td>
<td>1</td>
</tr>
<tr>
<td>Young’s modulus $E(\varepsilon)$ of the material</td>
<td>cone vibration</td>
<td>Band-pass (strain $\varepsilon$)</td>
<td>Band-pass (strain $\varepsilon$)</td>
<td>1</td>
</tr>
<tr>
<td>Speed of sound $c(p)$</td>
<td>nonlinear sound propagation</td>
<td>High-pass (sound pressure $p$)</td>
<td>High-pass (sound pressure $p$)</td>
<td>differentiator</td>
</tr>
<tr>
<td>Time delay $\tau(x)$</td>
<td>nonlinear sound radiation (Doppler effect)</td>
<td>High-pass (sound pressure $p$)</td>
<td>Low-pass (displacement $x$)</td>
<td>differentiator</td>
</tr>
</tbody>
</table>
More to this topic …

Reference:

Lecture „Sound quality of Audio Systems“ at the University of Technology, Dresden, Germany

Get a free poster for your workshop

Attend the annual three day block seminar (March 2019)
Demo: Interpretation

Tools of the KLIPPEL Analyzer:
• Transfer Function TRF (chirp stimulus)
• In-Situ-Compensation ISC)
• Nearfield Scanner (NFS)
Poll:

您是否更喜欢呈现和解读相对度量的失真？
Do you prefer to present and to interpret the distortion on a relative metric?

A. 不是（绝对分量和基波分量刻度相同）
   No, (absolute components on the same scale as the fundamental)

B. 对，参考于基波幅值响应$L_{fund}(f)$
   Yes, referred to the fundamental amplitude response $L_{fund}(f)$

C. 对，参考于基波均值（在频段上的平均）
   Yes, referred to the mean value of the fundamental (averaged over the frequency band)

D. 其他方法 Other methods
Harmonic Distortion – Absolute or Relative?

Amplitude of spectral components

Content of distortion in total signal

Rms-value of nth-order harmonic component

\[ d_n = \frac{p_n}{p_1} \times 100\% \]

rms-value of total signal

recommended - easy to interpret

Be careful - difficult to interpret
Room Influence

2nd-order harmonics measured at 8 locations

Variation 40 dB

Frequency [Hz]

[Percent]

100
10
1
0.1

10^2
10^3
Relative Harmonic Distortion

distortion referred to the total output signal

优点 Advantages:
• 失真分量参考于总输出 Refers distortion component to total output
• 解释由单音产生的谐波的可听度比绝对分量好（但不适用于音乐） Explains audibility of harmonics generated by a single tone better than absolute components (but not for music)

缺点Disadvantages:
• 线性响应H(f,r) 导致高复杂度 Linear Response H(f,r) causes high complexity
• 不同阶次的谐波无可比性 Harmonics of different order are not comparable
• 解读困难 Interpretation is difficult
• 没有精确考虑掩盖效应 Does not consider masking effect precisely

更加强大的扬声器诊断 More powerful for loudspeaker diagnostics:
• 将基波和谐波显示为绝对信号分量 Display fundamental and harmonics as absolute signal components
• 将谐波转换为扬声器输入（等效谐波失真IEC 60268-21） Transform harmonics to the loudspeaker input (equivalent harmonic distortion IEC 60268-21)
• 用感知模型评估失真的掩盖 Use perceptional modeling to evaluate the masking of the distortion
Equivalent Harmonic Input Distortion

Determine the distortion at the source

Inverse filter

Distorted input signal

\[ u'(r_1) \approx u'(r_2) \approx u'(r_3) \approx u'(t) \]

Equivalent harmonic input distortion

Distortion depends on linear transfer function

Sinusoidal stimulus

Harmonic Distortion

Sound field

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多路径中的非线性 Nonlinearity in Multidimensional Path

非线性音盆振动示例 for example nonlinear cone vibration

$H(f, r_1)\cdot p(r_1) = H(f, r_1)^{-1}\cdot u(r_1)$

$H(f, r_2)\cdot p(r_2) = H(f, r_2)^{-1}\cdot u(r_2)$

Equivalent Input distortion at Point $r_1$

Equivalent Input distortion at Point $r_2$

disagreement
Localization of Speaker Nonlinearity

扬声器非线性定位

声场中不同点处测量EID

EID measured at different points in the sound field

Distortion depend on measurement point

Nonlinearities located in one-dimensional signal path
Active Control Loudspeaker

- Only the equivalent input distortion (EID) can be compensated by an active control system!!

Active Speaker Linearization

主动控制系统只能补偿等效输入失真（EID）！ Only the equivalent input distortion (EID) can be compensated by an active control system!!

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等效谐波输入失真  Equivalent Harmonic Input Distortion
IEC 60268-21

好处 Benefits:

• 在主要失真产生处描述它们 Describe the dominant distortions where they are generated

• 与换能器、房间、距离、传感器等的后整形无关 Independent of the post-shaping from transducer, room, distance, sensor, ...

• 现场（办公室）、QC测试箱、消声室测量的结果相同 same results measured in-situ (office), QC-test box, anechoic room

• 易于解读 (平滑曲线、输入信号的百分比) Simple to interpret (smooth curves, percent of the input signal)

• 可以通过主动线性化 (DSP) 消除 Can be cancelled by active linearization (DSP)

实用建议 Practical Tip:

• 通过近场测量保证足够的SNR! Ensure sufficient SNR by performing near-field measurement!
Demo: Equivalent Input Distortion

Tools of the KLIPPEL Analyzer:

- Transfer Function TRF (chirp stimulus)
- TRF Voltage Stepping STEP
Poll:

您使用2次和3次失真分量用于扬声器诊断吗？
Do you use the 2\textsuperscript{nd}- and 3\textsuperscript{rd}-order distortion components for loudspeaker diagnostics?

- Yes
- No
Root Cause of the Harmonics
Symmetrical Nonlinearity

feed-forward system

Static nonlinearity

Symmetrical nonlinearity

odd-order distortion

Spectrum Pfar

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Distortion</th>
<th>Fundamental</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>250</td>
<td>3rd</td>
<td>3rd</td>
</tr>
<tr>
<td>500</td>
<td>5th</td>
<td>5th</td>
</tr>
<tr>
<td>750</td>
<td>3rd</td>
<td>3rd</td>
</tr>
<tr>
<td>1000</td>
<td>3rd</td>
<td>3rd</td>
</tr>
<tr>
<td>1250</td>
<td>5th</td>
<td>5th</td>
</tr>
<tr>
<td>1500</td>
<td>2nd</td>
<td>2nd</td>
</tr>
<tr>
<td>1750</td>
<td>4th</td>
<td>4th</td>
</tr>
<tr>
<td>2000</td>
<td>2nd</td>
<td>2nd</td>
</tr>
</tbody>
</table>

Force factor Bl vs. displacement X

Bl  [N/A]
Displacement  X  [mm]
Bl(X)

odd-order distortion
3rd
5th
2nd
4th
Root Cause of the Harmonics
Asymmetrical Nonlinearity

- Feed-forward system
- Static nonlinearity
- Asymmetrical nonlinearity
- Even-order distortion
- 2nd, 4th, 6th-order component

Graph showing harmonic distortion measurements with frequency on the x-axis and distortion in dB on the y-axis. Peaks at 2nd, 4th, and 6th order components are visible.

KLIPPEL LIVE #8: Harmonic Distortion Measurements - Best Practice, 41
Root Cause of the Harmonics
Asymmetrical Nonlinearity

A loudspeaker is a feedback system.

Asymmetrical nonlinearity

Even and odd-order distortion

Force factor $B_l$ vs. displacement $X$

Static nonlinearity loudspeaker is a feedback system

Distortion vs. Frequency

- Fundamental
- 2nd
- 3rd
- 4th
- 5th

Fundamental vs. Frequency

- 2nd
- 3rd
- 4th

KLIPPEL LIVE #8: Harmonic Distortion Measurements - Best Practice, 42
Poll:

Do you evaluate the higher-order distortion components?

A. No

B. Yes, 4th and 5th order

C. Yes, energetic sum of higher-order components of specified order (e.g. 6th ... 20th)

D. Yes, weighted higher-order distortion (HI-2, blat distortion)

E. Yes, other ways
Root Cause of the Harmonics

Hard or soft limiting nonlinearity

Spectrum of sound pressure signal (two-tone stimulus):

- High 2nd- and 3rd order distortion
- Large amplitude of all components
**Higher-Order Harmonic Distortion**

**HOHD as defined in IEC 60268-21**

\[
HOHD(f) = \sqrt{\sum_{n=N_i}^{N} \tilde{p}_{nf}^2(f)} \over \tilde{p}_{ref}(f) \times 100\%
\]

**State:**
- Lowest order \( N_i \)
- Highest order \( N \)

**Blat Distortion results from a design characteristic rather than a rub, buzz or tick type of unit defect**

**Weigthed harmonic Blat Distortion**

\[
L_{HI-2} = 10 \lg \left( \frac{\sum_{n=2}^{10} (w(n) \tilde{p}_{nf}(f))^2}{\tilde{p}_{ref}^2} \right)
\]

\[
w(n) = 4^{ld(n/4)}
\]

**TIP:**
- Measurement period ensures sufficient signal to noise ratio (SNR) during measurement
- Measure sound pressure in the near field!
Poll:

您是否在不同的输入电压下测量谐波失真来研究幅值压缩？Do you measure the harmonic distortion at different input voltages to investigate the amplitude compression?

- Yes
- No
Compression of 3rd-order Harmonic

Third-order harmonic distortion in percent (IEC 60268)

<table>
<thead>
<tr>
<th>Signal at IN1</th>
<th>0.50 V</th>
<th>1.57 V</th>
<th>2.64 V</th>
<th>3.71 V</th>
<th>4.79 V</th>
<th>5.86 V</th>
<th>6.93 V</th>
<th>8.00 V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent</td>
<td>80</td>
<td>70</td>
<td>60</td>
<td>50</td>
<td>40</td>
<td>30</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Frequency f1</td>
<td>4\times 10^1</td>
<td>6\times 10^1</td>
<td>8\times 10^1</td>
<td>10^2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Compression of 2\textsuperscript{nd}-order Harmonic Distortion

- Nonlinear Distortion depends on frequency and voltage
- Complicated amplitude characteristic (compression, reduction)
- Measurement versus amplitude also required (3D measurement)
Compressed in THD
Hard or soft limiting nonlinearity

Total harmonic distortion (THD) in percent

Steep but late increase
Early but slow increase

KLIPPEL LIVE #8: Harmonic Distortion Measurements - Best Practice, 49
Demo: Amplitude Compression of the Harmonic Distortion

Tools of the KLIPPEL Analyzer:

- Transfer Function TRF (chirp stimulus)
- TRF Voltage Stepping STEP
- 3D Distortion DIS
Discussion
Summary

Harmonic Distortion

• 谐波失真测量揭示了系统非线性的有用症状
  Harmonic distortion measurement reveals useful symptoms of system nonlinearities
• 通过使用扫频速度增加的对数chirp信号进行超快速测量
  Ultra-fast measurements can be performed by using logarithmic chirps with increasing sweep speed
• 等效输入谐波失真（EIHD）简化了结果的解读
  The Equivalent Input Harmonic Distortion (EIHD) simplifies the interpretation of the results
• 在不同幅值处的测量（电压步进）提供重要信息
  Measurement at different amplitudes (voltage stepping) provides important information
• 近场测量提高SNR
  Measurements in the near field improves SNR
Open Questions

Harmonic distortion measurements are convenient but don’t give a comprehensive picture of the nonlinear distortion!

第九期KLIPPEL live主题  The next 9th KLIPPEL live webinar entitled
互调失真 – 音乐不仅仅是单音信号
Intermodulation Distortion – music is more than a single tone
将讨论 will address the points:
• 如何按照IEC 60268-21用双音激励测试？
  How to test with a two-tone stimulus according IEC 60268-21？
• 为什么互调失真通常比THD大？ Why are the IM Distortion usually larger than the THD？
• 为什么幅度调制比相位调制重要？
  Why is amplitude modulation more critical than phase modulation？
• 如何简化互调测量？ How to simplify the intermodulation measurement？
• 如何进行多音测试？ How to perform multi-tone testing？
• 如何解读结果？ How to interpret the results？
1. Modern audio equipment needs output based testing
2. Standard acoustical tests performed in normal rooms
3. Drawing meaningful conclusions from 3D output measurement
4. Simulated standard condition at a single evaluation point
5. Maximum SPL – giving this value meaning
6. Selecting measurements with high diagnostic value
7. Amplitude Compression – less output at higher amplitudes
8. Harmonic Distortion Measurements – best practice
9. Intermodulation Distortion – audio is more than a single tone
10. Impulsive distortion - rub&buzz, abnormal behavior, defects
   -- small break --
11. Smart speaker testing with wireless audio input (July 22nd)
12. Benchmarking of audio products under standard conditions
13. Auralization of signal distortion – perceptual evaluation
14. Setting meaningful tolerances for signal distortion
15. Rating the maximum SPL value for product